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IV.

Magnetic Observations on the Boundary Line between the United States and Mexico, made in 1855, *under the Direction of* MAJOR W. H. EMORY, *United States Commissioner under the Treaty of* 1853; *and General Discussion of the Magnetic Observations made in Connection with the Mexican Boundary Surveys.*

RECOMPUTED BY J. E. HILGARD, U. S. COAST-SURVEY.

(*With a Map.*)

(*Communicated September* 8, 1856.)

I. MAGNETIC OBSERVATIONS IN 1855.

OBSERVATIONS of declination, dip, and absolute horizontal intensity were made at eight stations, being those at which astronomical observations were made in determining the boundary between the United States and Mexico, under the treaty of 1853. The magnetic observations were intrusted to Mr. Marine T. W. Chandler, who succeeded in obtaining very complete determinations, as the subjoined abstracts show.

The *declination* was obtained by referring the direction of the needle to the astronomical meridian carefully determined for the survey of the line. The needle of a goniometer by Young was found to show a fair mean of five good needles of different lengths, and was therefore relied on at subsequent stations. The results are given in the general table below.

Observations of *inclination* were made with a ten-inch dip-circle by Gambey, of superior construction. Two needles were used at each of the stations; and at three of them, viz. Carrizalillo, Espia, and Los Nogales, the poles were repeatedly reversed, so as to obtain the corrections to be applied when no reversal of poles was made. These corrections are +12′ for needle No. 1, and —15′ for No. 2, in the position of the poles called direct, and have been so applied in the following abstract of results.

Station.	Needle No. 1.		Needle No. 2.		Remarks.
	Dip.	No. of Sets.	Dip.	No. of Sets.	
	° ′		° ′		
Initial Point,	58 39	3	58 19	3	
Carrizalillo,	58 31	3	58 13	3	Poles reversed in each set.
Espia,	57 59	1	57 50	2	" " " "
Agua del Perro,	57 28	2	57 5	2	
San Luis Springs,	57 37	1	57 21	1	
San Bernardino,	57 19	4	56 58	4	
Santa Cruz River,	57 28	2	57 17	2	
Los Nogales,	57 13	1	57 1	1	Poles reversed in each set.

The difference of about 16′ between the results by the two needles is too large to admit of the mean being taken. An examination of the pivots having shown some corrosion on a pivot of No. 2, the probability is that the results by No. 1 are to be preferred, especially as the observations with that needle show a greater consistency among themselves. The results by No. 1 are therefore adopted in the general table.

Observations for horizontal intensity were made with a unifilar magnetometer by Jones. The deflections were measured on a nine-inch circle according to Lamont's method, in which the two magnets remain at right angles. In the vibration experiments, the time of 400 vibrations is usually observed, of which six values are obtained in each set, in the usual way. Experiments to determine the moment of inertia of the magnet and its attachments were made repeatedly by vibrating it loaded with a brass ring, marked No. 11, of which the outside diameter is 2.899 inches, the inside diameter 2.462 inches, and the weight 719.90 grains; hence its moment of inertia, K, $= 9.04$ expressed in feet and grains. The magnet used, marked X 7, is of the usual form, being a hollow cylinder of 0.3 inch in diameter, and 3.66 inches in length, and carrying a mirror. Its temperature coefficient was determined at Washington City in February, 1856, by vibrations at temperature near 30° and 70°, and was ascertained

$$q = 0.0003.$$

The following is an abstract of the observations; to which is to be added, that, in the experiments without the inertia ring, the effect of 90° of torsion was 7′.5; in those with the ring, 15′.

Abstract of Observations for Horizontal Intensity.

Station.	VIBRATIONS				DEFLECTIONS. $r = 1.3$ feet.		Date. 1855.
	Without Ring.		With Ring.				
	T Time of 1 Vibr.	Temperature.	T_r Time of 1 Vibr.	Temperature.	u	Temperature.	
	s.	°	s.	°	° '	°	
Initial Point,	3.795	74.5	7.946	69.5	2 29.6	61	
	3.795	59	7.935	63	28.7	53.5	
					30.0	41	
Mean,	3.795	67	7.941	66	2 29.4	52	January 4.
Carrizalillo,	3.817	70			2 31.2	59	
	3.823	71.5	7.983	76	2 31	67.5	
	3.826	83			2 29.9	64.5	
Mean,	3.822	75	7.983	76	2 30.7	64	March 1.
Espia,	3.770	63	7.910	70			March 22.
Agua del Perro,	3.791	63					April 3.
San Luis Springs,	3.751	61			2 30.0	64.5	
	3.757	73			2 30.0	66.5	
					2 27.0	65	
Mean,	3.754	67			2 29.0	65	April 19.
San Bernardino,	3.776	78.5					
	3.778	82.5					
	3.764	81					
Mean,	3.773	81					April 28.
Santa Cruz River,	3.798	72					
	3.804	74					
Mean,	3.801	73					May 14.
Los Nogales,	3.805	94	7.949	80	2 26.5	81.5	
					25.2	83	
Mean,					2 25.85	82	June 16.

From the preceding data we first deduce the moment of inertia, K, of the magnet and its attachments, by the equation $K = K_r \frac{T^2}{T_r^2 - T^2}$, where T_r and T are the terms of one vibration with and without the inertia ring, corrected for torsion, and reduced to the temperature of experiments without the ring, and obtain the following values: —

At Initial Point,	$K = 2.669$
Carrizalillo,	2.680
Espia,	2.659
Los Nogales,	2.668
Mean,	2.669

From the experiments of deflection we next deduce the values of ratio of m, the magnetic moment of the magnet, to X, the horizontal component of the earth's form, by the expression $\frac{m}{X} = \frac{1}{2} r^3 \sin u$, and obtain at

Initial Point,	$\frac{m}{X} =$ 0.0477,	temp. 52°
Carrizalillo,	0.0481,	" 64°
San Luis,	0.0476,	" 65°
Los Nogales,	0.0466,	" 82°

Computing for the same stations the product $m\,X = \frac{\pi^2 K}{T^2}$, where T is corrected for torsion, and reduced to the temperature of the corresponding deflections, and eliminating X, we get the following values of m.

Station.	Date.	m	Temperature.	m reduced to 66°.
Initial Point,	Jan. 4	0.2959	52°	0.2947
Carrizalillo,	March 1	0.2951	64	0.2949
San Luis,	April 19	0.2982	65	0.2981
Los Nogales,	June 16	0.2915	82	0.2929

Although the difference in these values of m may be in a great measure due to errors of observations, rather than to fluctuations in the magnetism of the magnet, still the best results appear to be obtained by using the above values of m for the respective stations, and assuming a uniform rate of change during the intervals.

Computing, lastly, $m\,X$ for each of the stations, and dividing by m determined in the manner indicated and reduced to the temperature of the vibrations, we obtain the values of X given in the subjoined table, which exhibits collectively the results obtained.

General Table of Results.

Station.	Latitude.	Longitude.	Declination East.	Dip.	Horizontal Intensity.	Total Intensity.
Initial Point,	31° 47′	106° 28′	11° 55′	58° 39′	6.202	11.92
Carrizalillo,	31 51	107 56	12 2	58 31	6.125	11.73
Espia,	31 21	107 56	12 5	57 59	6.242	11.77
Agua del Perro,	31 21	108 20	11 58	57 28	6.156	11.45
San Luis Springs,	31 20	108 48	11 45	57 37	6.265	11.70
San Bernardino,	31 20	109 14	11 45	57 19	6.252	11.58
Santa Cruz River,	31 18	110 31	12 13	57 28	6.169	11.47
Los Nogales,	31 21	110 51	11 45	57 13	6.262	11.56

II. Discussion of Lines of equal Magnetic Declination, Dip, and Horizontal Intensity.

In this discussion, the observations made in previous years in connection with the Mexican boundary surveys, and published in the fifth volume, new series, of the Memoirs of the Academy, have been combined with those communicated in the present paper. Observations made under the direction of Professor A. D. Bache, Superintendent of the Coast Survey, at stations Dollar Point, East Base, and Jupiter, near Galveston, Texas, and near San Diego, Monterey, and San Francisco, and affording important co-ordinates for the curvature of the lines, have also been introduced; likewise, an observation of the declination at the Great Salt Lake, by Captain Howard Stansbury, U. S. Topographical Engineers, published in his report of the survey of that region.

The method employed in determining the lines of equal declination and dip was partly graphical and partly analytical, being the same pursued by Professor Bache and Mr. J. E. Hilgard in their discussion of the Coast-Survey magnetic observations. (Coast-Survey Report for 1855, Appendix, p. 47.) The stations were projected on a map, and their positions referred to a right line graphically assumed as axis of co-ordinates, the origin being chosen about the mean position of the stations, and the direction so as nearly to divide the positive and negative ordinates equally.

The co-ordinates being read off on any convenient linear scale, conditional equations are formed for each station or group of stations, and the whole scheme is solved by the method of least squares. The conditional equations representing an interpolation by second differences are of the form,

$$V = V_0 + v + x\,X + y\,Y + z\,X\,Y + p\,X^2 + q\,y^2,$$

when V is the observed declination (or dip);

V_0, the assumed declination at the origin; v, the correction to be applied;

X and Y, co-ordinates of position.

x, y, z, p, q, coefficients to be determined.

The solution of a considerable number of such equations involves a great deal of labor, which the results amply repay, however. The process being well known, there is no occasion to give the steps of the calculations in this place. After determining the coefficients, the co-ordinates of points in the lines sought were computed, the lines projected on the map, and the latitudes and longitudes of points read off and tabulated.

In the absence of any data to determine the secular changes, the results are doubtless liable to an uncertainty from that source. We know, however, that the changes are small, and, for the limited period over which the observations extend, they may be considered as merged in the local errors, and the average date of 1852 as belonging to the resulting lines on the map.

The following tables give a general *résumé* of the observations, and the corresponding values in the computed system; also the residuals, the distribution of which is the best evidence of the successful representation of the general facts involved.

The geographical position of points in the lines of equal declination and dip — isogonic and isoclinal lines — are also given in tables from which they may be readily projected in any map.

Observations of Declinations.

No.	Station.	Latitude.	Longitude.	Date.	Declination East, Observed.	Declination East, Computed.	Residual, Comp. — Obs.
		° ′	° ′		° ′	° ′	′
1	Dollar Point,	29 26	94 53	1848	8 57	9 3	+ 6
2	East Base,	29 13	94 55	1853	9 5	9 2	— 3
3	Jupiter,	28 55	95 20	1853	9 9	9 10	+ 1
4	Rio Grande, Mouth,	25 57	97 7	1853	9 0	8 56	— 4
5	Ringgold Barracks,	26 23	98 43	1853	9 15	9 18	+ 3
6	Fort McIntosh,	27 30	100 5	1852	10 0	9 46	— 4
7	Eagle Pass,	28 42	100 30	1852	10 1	10 7	+ 6
8	Presidio del Norte,	29 34	104 25	1852	10 16	10 53	+37
9	Mouth of Cañon,	31 2	105 37	1852	12 1	11 28	—33
10	Emory's Initial Point,	31 47	106 28	1855	11 55	11 48	— 7
11	Frontera,	31 49	106 29	1852	12 24	11 49	+25
12	Doña Ana,	32 22	106 45	1851	12 7	12 2	— 5
13	Carrizalillo,	31 51	107 56	1855	12 2	11 58	— 4
14	Espia,	31 21	107 56	1855	12 5	11 48	—17
15	Copper Mines,	32 48	108 4	1851	11 22	12 18	+56
16	Agua del Perro,	31 21	108 20	1855	11 59	11 50	— 9
17	San Luis Springs,	31 20	108 48	1855	11 45	11 52	+ 7
18	San Bernardino,	31 20	109 14	1855	11 45	11 53	+ 8
19	Santa Cruz River,	31 18	110 31	1855	11 45	11 58	+13
20	Los Nogales,	31 21	110 51	1855	12 13	12 0	—13
21	San Pedro,	32 59	110 40	1851	12 25	12 37	+12
22	Pimos Villages,	33 7	111 44	1851	12 52	12 46	— 6
23	Gila Junction,	32 43	114 53	1851	12 50	12 45	— 5
24	San Isabel,	33 9	116 38	1852	12 34	12 55	+21
25	Camp Riley,	32 36	117 5	1849	12 57	12 44	—13
26	San Diego,	32 42	117 12	1849	13 15	12 47	—28
27	San Diego C. S.,	32 41	117 13	1851	12 29	12 48	+19
28	Monterey,	36 38	121 54	1851	14 58	14 54	— 4
29	San Francisco,	37 48	122 27	1852	15 30	15 34	+ 4
30	Salt Lake City,	40 46	112 8	1850	15 34	15 34	0

Isogonic Lines.

Geographical Positions of Points.

Longitude.	9°	10°	11°	12°	13°	14°	15°	Declination East.
95	28° 50′							Latitude.
96	27 28							
97	26 23							
98	25 34	30° 17′						
99	24 57	29 18						
100		28 32						
101		27 54						
102		27 27	31° 12′					
103		27 4	30 35					
104			30 7					
105			29 45	33° 8′				
106			29 27	32 36				
107			29 14	32 13				
108			29 4	31 54	34° 54′			
109				31 39	34 29			
110				31 28	34 9			
111				31 20	33 54			
112				31 14	33 43			
113				31 10	33 33	36° 2′		
114					33 24	35 47		
115					33 17	35 35	38° 3′	
116					33 14	35 25	37 46	
117					33 12	35 17	37 31	
118						35 10	37 19	
119						35 5	37 9	
120						35 2	37 1	
121						35 0	36 54	
122						34 58	36 48	
123							36 44	
124							36 41	

Observations of Dip.

No.	Station.	Latitude.	Longitude.	Date.	Dip, Observed.	Dip, Computed.	Residual, Comp. — Obs.
1	Dollar Point,	29° 26′	94° 53′	1848	57° 58′	58° 0′	+ 2′
2	East Base,	29 13	94 55	1853	57 42	57 45	+ 3
3	Jupiter,	28 55	95 20	1853	57 12	57 7	— 5
4	Rio Grande, Mouth,	25 57	97 7	1853	52 23	52 14	— 9
5	Ringgold Barracks,	26 23	98 43	1853	52 27	52 35	+ 8
6	Fort McIntosh,	27 30	100 5	1852	54 7	53 58	— 9
7	Fort Duncan,	28 42	100 30	1852	55 31	55 35	+ 4
8	Presidio del Norte,	29 34	104 25	1852	55 41	55 59	+18
9	Mouth of Cañon,	31 2	105 37	1852	57 38	57 45	+ 7
10	San Elceario,	31 35	106 16	1852	58 57	58 17	—30
11	Frontera,	31 48	106 33	1852	59 5	58 32	—33
12	Doña Ana,	32 22	106 47	1851	59 6	59 8	+ 2
13	IX.,	22 22	107 24	1851	59 9	59 0	— 9
14	Copper Mines,	32 47	108 4	1851	59 17	59 23	+ 6

No.	Station.	Latitude.	Longitude.	Date.	Dip, Observed.	Dip, Computed.	Residual, Comp. — Obs.
15	Emory's Initial Point,	31° 47′	106° 28′	1855	58° 39′	58° 30′	— 9′
16	Carrizalillo,	31 51	107 56	1855	58 31	58 23	— 8
17	Espia,	31 21	107 56	1855	57 39	57 41	—18
18	Agua del Perro,	31 21	108 20	1855	57 28	57 40	+12
19	San Luis,	31 20	108 48	1855	57 37	57 36	— 1
20	San Bernardino,	31 20	109 14	1855	57 19	57 30	+11
21	Santa Cruz River,	31 18	110 31	1855	57 28	57 21	— 7
22	Los Nogales.	31 21	110 51	1855	57 13	57 21	+ 8
23	Ojo de Inez,	32 45	108 14	1851	59 18	59 22	+ 5
24	Station 1,	32 50	109 34	1851	59 19	59 12	— 7
25	" 2,	32 50	109 37	1851	59 12	59 12	0
26	" 3,	32 53	109 44	1851	59 12	59 15	+ 3
27	" 4,	32 57	109 49	1851	59 20	59 18	— 2
28	" 5,	33 4	109 55	1851	59 27	59 25	— 2
29	" 6,	33 6	110 0	1851	59 38	59 30	— 8
30	" 7,	33 10	110 3	1851	59 42	59 33	— 9
31	" 8,	33 12	110 10	1851	59 37	59 35	— 2
32	" 9,	33 13	110 19	1851	59 45	59 35	—10
33	" 10,	33 12	110 19	1851	59 34	59 30	— 4
34	" 12,	33 9	110 26	1851	59 37	59 28	— 9
35	" 13,	33 9	110 28	1851	58 58	59 26	+28
36	" 15,	33 9	110 31	1851	59 28	59 25	— 3
37	" 17,	33 12	110 42	1851	59 23	59 28	+ 5
38	" 19,	33 5	110 35	1851	59 5	59 19	+14
39	" 20,	32 59	110 40	1851	59 11	59 13	+ 2
40	" 21,	33 3	110 46	1851	58 59	59 16	+17
41	" 22,	33 5	110 50	1851	59 13	59 18	+ 5
42	" 23,	33 7	110 55	1851	59 23	59 20	— 3
43	" 24,	33 6	111 2	1851	59 20	59 18	— 2
44	" 26,	33 4	111 11	1851	59 25	59 14	—11
45	" 27,	33 3	111 16	1851	59 20	59 12	— 8
46	" 28,	33 1	111 23	1851	59 16	59 10	— 6
47	" 29,	33 4	111 34	1851	59 6	59 10	+ 4
48	" 30,	33 8	111 44	1851	59 6	59 14	+ 8
49	" 31,	33 10	111 54	1851	59 28	59 16	—12
50	" 32,	33 9	111 57	1851	59 22	59 16	— 6
51	" 38,	33 0	112 39	1851	58 53	58 57	+ 4
52	" 39,	32 59	112 43	1851	58 49	58 56	+ 7
53	" 40,	33 2	112 55	1851	59 16	58 59	—17
54	" 42,	32 58	113 11	1851	59 17	58 52	—25
55	" 43,	32 49	113 33	1851	58 43	58 39	— 4
56	" 44,	32 44	113 50	1851	58 30	58 30	0
57	" 45,	32 41	114 5	1851	58 25	58 26	+ 1
58	Gila Junction,	32 43	114 33	1851	58 30	58 28	— 2
59	New River,	32 42	115 25	1849	58 19	58 20	+ 1
60	Santa Isabella,	33 8	116 41	1849	58 48	58 44	— 4
61	Santa Maria,	33 2	116 51	1849	58 42	58 37	— 5
62	San Diego,	32 42	117 8	1849	57 33	58 14	+41
63	San Diego C. S.,	32 41	117 13	1851	57 38	58 12	+34
64	San Francisco,	37 46	122 27	1852	62 32	62 40	+ 8
65	Sacramento,	38 34	121 17	1852	64 3	63 37	—26

Isoclinal Lines.

Geographical Positions of Points.

Longitude.	52°	53°	54°	55°	56°	57°	58°	59°	60°	61°	62°	63°	Dip.
95	25° 30′	26° 9′	26° 48′	27° 27′	28° 7′	28° 47′	29° 26′						Latitude.
96	25 38	26 18	26 57	27 37	28 17	28 57	29 37						
97	25 46	26 26	27 6	27 47	28 27	29 8	29 49						
98	25 34	26 35	27 15	27 56	28 37	29 18	30 0						
99	26 2	26 43	27 24	28 5	28 47	29 28	30 11						
100	26 9	26 51	27 33	28 14	28 56	29 38	30 21						
101		26 59	27 41	28 22	29 5	29 48	30 22						
102			27 49	28 31	29 14	29 57	30 42						
103				28 40	29 23	30 6	30 52						
104					29 32	30 16	31 2						
105					29 40	30 24	31 11	31° 59′	32° 49′				
106					29 47	30 32	31 20	32 9	32 58				
107					29 54	30 39	31 28	32 18	33 7				
108					30 0	30 46	31 36	32 27	33 16				
109					29 5	30 53	31 43	32 35	33 25				
110					30 10	30 59	31 50	32 43	33 33				
111						31 5	31 57	32 50	33 41				
112						31 11	32 4	32 57	33 49				
113						31 17	32 11	33 4	33 57				
114						31 22	32 16	33 10	34 4				
115						31 26	32 21	33 16	34 11	35° 7′			
116						31 31	32 26	33 22	34 18	35 15			
117						31 35	32 31	33 28	34 24	35 22	36° 19′		
118						31 39	32 26	33 33	34 30	35 29	36 27		
119										35 36	36 35	37° 35′	
120											36 42	37 45	
121											36 49	37 54	
122												38 2	
123												38 11	

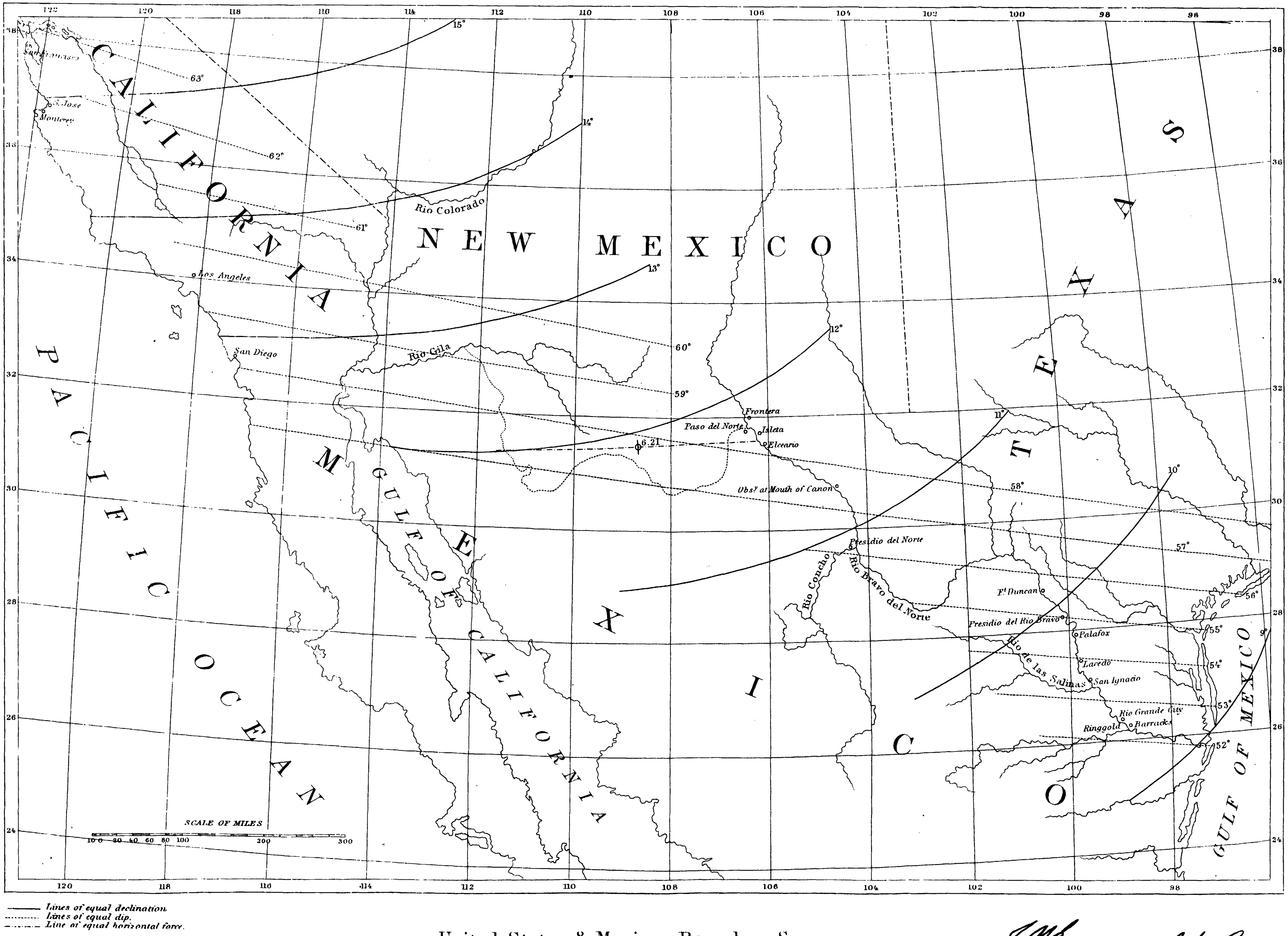
Horizontal Intensity. — Combining the eight stations of 1855 among themselves, we obtain as a mean result, in latitude 31° 27′, longitude 108° 45′, $X = 6.21$, with a probable error of ± 0.01; also an increase of $+ 0.10$ in going south 30′.7 or east 506′, and the direction of the line of equal horizontal intensity N. 87½° E.

It may be observed, that this rate of change in going south is evidently too large, for according to the decrease of dip it would require a southing of 42′ to cause an increase of the horizontal force of $+ 0.10$, if the total force was constant; but as the latter also decreases in going south, the actual rate of change of horizontal force is probably only half of that above obtained. Moreover, when we consider that the same value of X is found on the coast of Mississippi, between New Orleans and Mobile, we see that the small increase in going east should be decrease of similar amount, and that the direction of the line should be about N. 94° E. The distribution of stations is such that these discrepancies in the rate of change are quite within the probable errors of observation and station errors; nor is the value of the mean result affected thereby, which forms a valuable datum in absolute measure, in an almost inaccessible region of the globe.

In order to compare this measure of force with that previously obtained on the northern line by observations with a Fox apparatus, and expressed in the arbitrary scale, we may have recourse to the observations of Captain Lefroy at Toronto, which gives the total force in British units = 13.86 at the same time that it is found 1.836 in the arbitrary scale. Applying the same ratio to our mean total intensity, 11.65, we find 1.543, and we have the following comparison: —

Latitude.	Longitude.	Total Intensity.
31° 27′	108° 45′	1.543
32 43	108 30	1.580

the latter from three stations in 1851; exhibiting a closer correspondence than might be expected from the circuitous comparison involved.



United States & Mexican Boundary Survey.

WHEmory U.S. Comr: